

Baker 1983

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Parasites of locusts and grasshoppers

Agfact AE.2. First edition 1983
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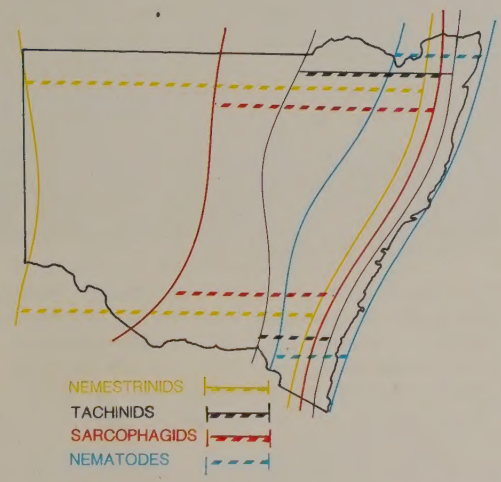
The abundance of parasites and predators of locusts and grasshoppers varies from district to district and from season to season. The degree of control they exert on grasshopper populations depends on:

- the number of species in the parasite complex;
- the size and stability of the host populations; and
- seasonal conditions.

The parasitic species are not uniformly distributed in New South Wales. Many species are well represented in the eastern half of the State, but few are present in the semi-arid, western districts of the State. The relative scarcity of parasites in the far west may be partly the reason for the importance of plagues arising in this region.

Parasites are totally dependent on the availability of hosts for survival. If host numbers are low, parasite numbers are even lower. An increase in grasshopper numbers (either locally or from immigration), may provide an unlimited number of hosts, but the ability of parasites to respond is controlled by many factors. For example, the number of generations of host and parasite during a season, and the relative fecundity of host and parasite, influence the rate at which parasites increase in relation to their host. As a result, the

A tachinid larva emerging from an adult wingless grasshopper. Fly parasites are not host specific, utilising whichever grasshopper or locust species is most abundant.



The distribution of locust parasites within New South Wales. Both the number of species and their abundance decline in the western half of the State. Abnormal seasons change the distribution and abundance of the parasite species, modifying the control they exert on locust and grasshopper populations.

Scelio wasps emerging from an Australian plague locust egg pod. Their attack on eggs may substantially reduce the size of a locust hatching. (Photo: M. Hill)



time taken for parasite numbers to respond to increased host numbers, and the size of the response, is highly variable.

Seasonal conditions also have a major influence on the abundance of parasites. Nematodes are inactive under dry conditions, but may be important parasites in seasons receiving normal rainfall. The survival, efficiency of host contact, and fecundity of all parasites is to some extent influenced by climatic condition. Fortunately, not all parasites are affected in the same way; adverse conditions for one parasite species may be favourable for another.

The complexity of the locust/parasite association and the vagaries of weather makes assessment of their role in the control of any particular locust outbreak extremely difficult. To minimise crop damage and limit the rate of spread of an outbreak, we remain dependent on chemical control methods. The duration of a control campaign required to end an outbreak depends partly on the amount of complementary control

exerted by parasites. For this reason, extreme care is taken to ensure minimal harm is caused to the parasite complex during a campaign.

This Agfact lists parasites and predators under the host stage attacked (for example parasites of eggs). The common name (for example, scelio wasps), is followed in each sub-heading by the order and then the family (Hymenoptera : Scelionidae) to which the parasite belongs. In the text the genus is followed by the species name (*Scelio fulgidus*) and both are set in italics. Where several species belonging to the same genus are listed, the second and following names abbreviate the genus name to a single capital letter (for example, *Scelio parvicornis* is written as *S. parvicornis*).

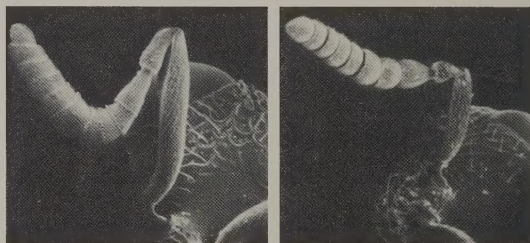
An illustrated key to the major parasites, predators and diseases of locusts and grasshoppers in New South Wales is on pages 14-15, and a summary of biological control agents of locusts and grasshoppers is on the back cover.

PARASITES OF EGGS

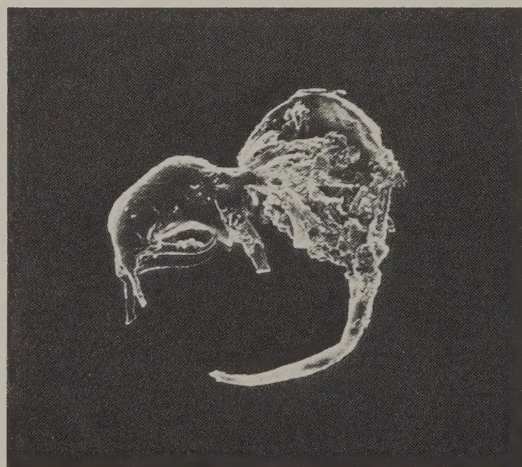
Scelio wasps (Hymenoptera:Scelionidae)

All scelionid parasites of grasshopper eggs belong to a single genus, *Scelio*. There are 32 described species in Australia, but hosts are unknown for most. Scelio wasps tend to be host specific: each species being restricted to grasshopper species whose eggs are of a similar size.

In New South Wales the most important species and their hosts (in brackets) are; *Scelio fulgidus* (Australian plague locust); *S. parvicornis* (Australian plague locust); *S. bipartitus* (migratory locust, yellow-winged locust); *S. improcerus* (wingless



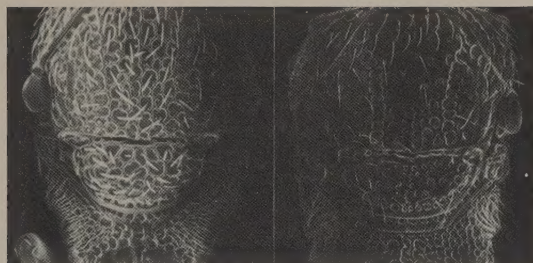
Antennae of adult scelio wasps. Female (left) and male (right). (Electron micrograph: M. Horwood)



First instar *S. parvicornis* larva. Less than 0.5 mm long, the larva appears as a small bubble in the yolk of the grasshopper egg. At high magnification it is a most improbable looking larva "with the head of a lion and the body of



a mouse". The head is equipped with long curved jaws and a toothed appendage used to grasp while the jaws destroy the grasshopper embryo.



Dorsal (top) view of the thorax of *Scelio bipartitus* (left) and *S. fulgidus* (right). At high magnification differences can be seen between species in body sculpturing and bristle patterns. (Electron micrograph: M. Horwood)

grasshopper); *S. chortoicetes* (small plague grasshopper).

All scelio wasps have a similar biology: an adult female enters a host egg pod by burrowing through the froth plug soon after the grasshopper egg pod is laid; the female pierces each host egg and deposits an egg in the yolk; the scelio wasp egg hatches during the water uptake phase of the host egg and the first instar (the youngest larval stage) larva immediately destroys the grasshopper embryo.

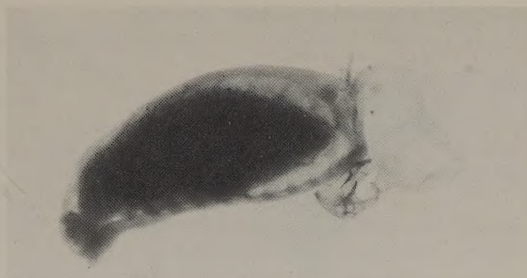
Under cool to cold conditions the first instar larva enters a facultative diapause (a period of suspended development). This ability to diapause synchronises the development of the parasite and its host. In summer larval development is uninterrupted.

When fully grown, the scelio wasp larva pupates in the host egg and transforms into an adult. Scelio wasps take one to two weeks longer to complete development than do unparasitised grasshopper eggs. Adults may remain dormant in the host egg, emerging irregularly over a period of two to four weeks. Typically no hoppers emerge from pods containing parasitised eggs as unhatched parasitised eggs (in the upper portion of the pod) block their emergence.

Adults may be found flying close to the ground during sunny periods, or sheltering in cracks in the soil under cool conditions.

A most important species is *S. fulgidus* which parasitises the eggs of the Australian plague locust, at times causing very high egg mortality. It is distributed throughout New South Wales west of the Great Dividing Range. If the same district is used for breeding by the Australian plague locust for several successive generations, a rapid increase in parasitism may occur (typically 1-4; 10-30; and 70-90 per cent of eggs are parasitised in each of three successive generations).

Migration of Australian plague locust swarms does not necessarily mean that they escape from egg



Second instar *S. parvicornis* larva. The skin of the first instar larva can be seen adhering to the end of the second instar larva. The second instar has a blind gut, storing consumed egg yolk. (Photo: M. Hill)



Third instar *S. parvicornis* larva. The gut remains blind. Third instar larvae consume remaining egg yolk and grow to fill the host egg. (Photo: M. Hill)



Pupa of *S. fulgidus*. The larva pupates inside the host egg. The gut opens and milky excretion accumulates at the posterior (back) end of the egg. An air space is produced around the body of the pupa. When exposed to the air, the surface of a parasitised grasshopper egg dries out rapidly over the air space, but remains moist over the excretion. This results in a characteristic two-toned appearance of parasitised eggs. (Photo: M. Hill)

parasites: recent studies by CSIRO indicate that the winds which aid locust migration also disperse scelio wasp populations to the same general area.

Recognition of the important role played by scelio wasps in the natural control of locusts has led to control strategies which cause minimal harm to wasp populations: locust hatchings are not treated until they have marched away from egg beds; and the aerial treatment of locust swarms ceases once egg laying has started.

Bee fly (Diptera:Nemestrinidae)

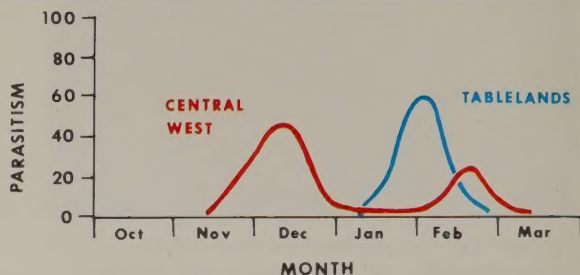
A single species, *Trichopsidea oestracea*, is a widespread parasite of locusts and grasshoppers throughout the mainland and Tasmania.

Female bee flies lay eggs on standing dead timber. When they hatch, the small larvae are transported by wind, making random contact with hosts. Both nymph and adult locusts and grasshoppers are parasitised but bee flies are most active during the adult stage of the host. Female hosts are more frequently parasitised than males, due to their larger size; and larger grasshopper species are more frequently parasitised than are smaller species.

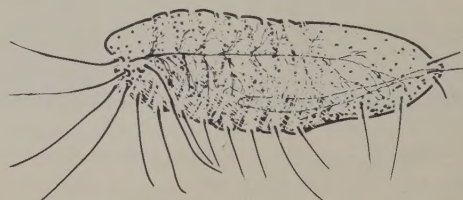
The bee fly is favoured by dry conditions, and in all districts parasitism is greater during seasons of below average rainfall. This is believed to be due to sparse vegetative cover allowing more frequent host contact. A series of dry early summers can change the relative abundance of grasshopper species as a result of different levels of attack by the bee fly. Larger grasshopper species tend to be quickly eliminated with smaller species becoming dominant.



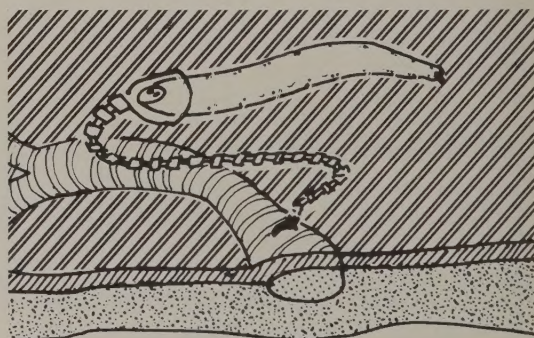
Adult female bee fly: so called because of a resemblance to bees and because adults emit a shrill whine when flying. The adult flies, which do not feed, are rarely seen, being active for only a short period each year. The female produces 8000 — 10 000 eggs, usually laid on standing dead timber such as stumps and fence posts. (Photo: M. Hill)



Seasonal abundance of the bee fly, *Trichopsidea oestracea*. There are up to three generations each year, though the majority of larvae produced in each generation enter diapause, emerging as adults the next season. In the central west, adults emerge in late October-November from the diapause part of all generations of the previous season. Parasitism of grasshoppers is well synchronised, peaking in early-mid December. After emerging from their host the majority of larvae diapause in the pre-pupal stage. A minority pupate, and produce a partial second generation. The majority of the progeny of this second generation again diapause, and a partial third generation is rarely produced. In the tablelands there is only a single generation each year; adult emergence takes place in December, with parasitism of grasshoppers peaking in late January



First instar bee fly larvae. Minute and covered with long hairs, the first instar larvae are spread by the wind. The larva enters the host through an intersegmental membrane (a soft, flexible membrane between the body sections) and attaches itself to a trachea (breathing tube).



Second instar bee fly larva. The slender larva is a pale yellow colour. The larva breathes via a long respiratory funnel attached to a host trachea.

Bee flies are active for only a short time each season. Host contact is synchronised, as is subsequent development of the larvae within the host. Larvae develop in the host for a period of three weeks in warm semi-arid areas, and for five weeks in cool tableland areas. The major period of parasite activity coincides with the fledging (wing formation) and early adult stage of the host.

Although the bee flies' active period is brief, they still have a significant role in the control of locusts. Very high levels of parasitism (60-80 per cent) have been recorded, and those locusts parasitised die before laying eggs.

Fortunately, insecticide control is avoided during the period when bee flies are active. Australian plague locust control ceases when bands of final instar nymphs disperse, and is not resumed until swarm formation some time after fledging. This lull in control operations coincides with peak activity by bee flies.



A woodcut of a final instar bee fly larva drawn by Olliff in 1891 when this parasite was first recorded from Australian plague locusts collected in the Wagga Wagga area.



Ovaries of female Australian plague locust: parasitised by a bee fly larva (bottom); and unparasitised (top). There is no egg development in the ovaries of parasitised females due to disrupted host metabolism. Using biochemical means the bee fly larva induces the host to convert nutrients to fat rather than for use in egg production. The fat builds up in the host during the parasite's development and is eaten by the parasite in a massive meal immediately before emergence.



A final instar bee fly larva emerging from an adult wingless grasshopper. (Photo: M. Hill)



Emergence of adult bee fly. The pupa (left) is not encased in any protective covering. Before adult emergence the pupa wriggles its way to the soil surface, and the adult emerges as it lies exposed on the ground. Pupal skins can be found scattered over the ground following the synchronised emergence of adults in early summer. (Photo: R. Pigott)

Tachinid flies (Diptera:Tachinidae)

Two genera of tachinids, *Ceracia* and *Phorocerosoma*, are parasites of grasshoppers in Australia. Only one species, *Ceracia fergusonii*, is commonly found in New South Wales. Tachinid flies have a wide host range, including both the Australian plague locust and the wingless grasshopper.

Female tachinid flies lay eggs directly onto the host. Both nymphs and adult locusts and grasshoppers are attacked, but nymphs appear to be successfully attacked more often.

Tachinid flies are found on the tablelands and western slopes, but are rare west of the Darling River.

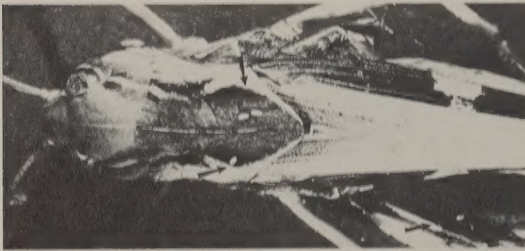
Parasitism rates are usually modest (less than 10 per cent) with a relatively slow rate of turnover. Tachinid flies are therefore considered the least important of the parasitic flies which attack locusts and grasshoppers.

Winter is spent in the pupal stage with adults emerging in October-November. Several generations (four to five) arise during a season but there is no evident build-up in parasitism levels towards the end of the season.

Tachinid flies are themselves attacked by a wasp parasite, *Perilampus australis*.



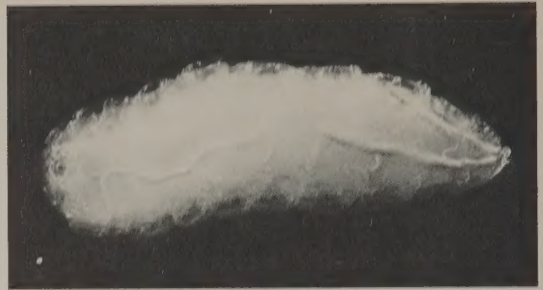
Adult female *Ceracia fergusonii*. A rather bristly fly, with a chequered black and reddish-brown body.



Eggs of the tachinid fly, *C. fergusonii*. Eggs are laid directly onto the host and adhered with a sticky secretion. On hatching the small larva burrows through the base of the egg and enters the host. Entry is helped by moulting of the host.



First instar *C. fergusonii* larva: The first instar larva has a distinctive, spade shaped, rasping mouthpart (the infrabuccal plate). Soon after entering the host the larva attaches itself to a major host trachea (breathing tube) and a respiratory funnel (not shown) is produced. (Photo: M. Hill)



Second instar *C. fergusonii* larvae. Posterior (back) end (right) is tapered and ends with a pair of prominent, posterior spiracles (external openings of trachea). The larva lies with its posterior end encased in a respiratory funnel, feeding only on host organs which are within reach. (Photo: M. Hill)



Third instar *C. fergusonii* larva. The posterior spiracles darken, becoming very conspicuous. The larva remains fixed in position, breathing via a respiratory funnel attached to a host trachea. When fully fed (10-14 days after entering the host) the larva emerges by pushing through an intersegmental membrane.



Posterior spiracle of *C. fergusonii* puparium. The posterior spiracles of the third instar larva are retained after the larva emerges from the host and pupates. Pupation takes place in the soil, the adult fly emerging after 12-15 days. (Electron micrograph: B. Loudon)

Sarcophagid flies (Diptera:Sarcophagidae)

Four species of sarcophagids are parasites of locusts and grasshoppers in Australia. All belong to the genus *Blaesoxipha* and three species, *Blaesoxipha pachytyli*, *B. gemina*, and *B. similis*, are found in New South Wales. While *B. gemina* has only been recorded on the north west slopes and plains, and *B. similis* only on the north coast, *B. pachytyli* is widely distributed and is an important parasite of all economic species of locusts and grasshoppers.

Female sarcophagid flies incubate eggs internally and small larvae are laid on the host where they enter through an intersegmental membrane. Both nymphs and adult locusts are attacked. Sarcophagid flies are widely distributed on the tablelands, western slopes and plains, but are rare in the western arid half of the State.

B. pachytyli is an important parasite of the Australian plague locust in the inner country. It persists between outbreaks by using alternative grasshopper hosts. When the Australian plague locust invades the inner country, *B. pachytyli* is quick to take advantage of the increased number of hosts. If a locust outbreak persists in an area, *B. pachytyli* achieves very high levels of parasitism and may initiate a recession.

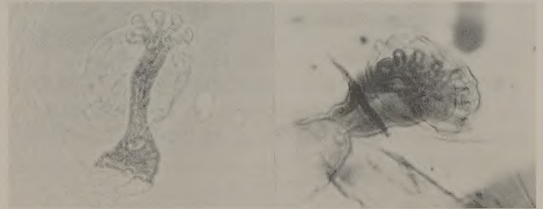
Parasitised locusts die when larvae emerge. The level of parasitism in a population is sustained by continuous attack on the population. At any one time, the parasitism rate is usually modest (5-20 per cent), but given the rapid turnover of parasitised hosts, the cumulative mortality is very substantial.



Posterior spiracle of third instar *B. pachytyli* larva. After emerging from the host, the third instar larva enters the soil and pupates. An adult fly emerges after 9-12 days.



First instar *B. pachytyli* larvae. The first instar larva is equipped with sharp mouth-hooks which are used to gain entry to the host. The body is covered with rows of short, backward pointing bristles which also help entry to the host. The larva is free-ranging within the host.



The anterior spiracle of a second instar (left) and a third instar (right) *B. pachytyli* larva.



Third instar *B. pachytyli* larva. The posterior end (left) is broad and blunt. The posterior spiracles consist of a pair of inconspicuous plates, recessed in a cavity at the posterior end of the body. Larvae move freely around the body cavity of the host feeding on fatty tissue, muscles, and reproductive organs. When fully fed (4-6 days after entering the host) the larvae emerge through the neck membrane.



Adult female *Blaesoxipha pachytyli*. Females are a dusty, olive-brown colour with cherry-red eyes. The legs are a light reddish-brown. Males, which are larger than females, are a grey colour with three glossy black stripes on the thorax. The abdomen is chequered in black and grey. (Drawing: E.H. Zeck)

Nematode worms (Nematoda:Mermithidae)

There are two genera of mermithid nematode worms which parasitise locusts and grasshoppers in New South Wales: *Amphimermis* (eggs laid in soil) and *Mermis* (eggs laid on vegetation). Nematode parasitism is typically a combination of both groups.

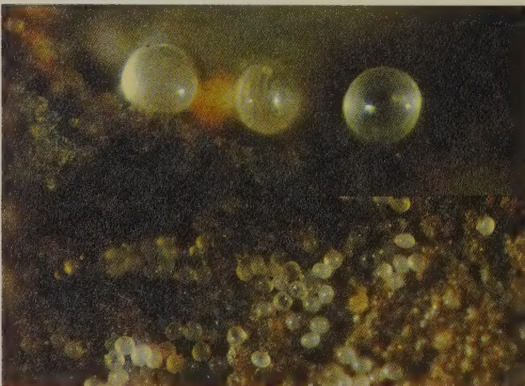
Nematodes are important parasites of locusts and grasshoppers in high rainfall areas, especially in seasons of above average rainfall. While nematodes play a significant role in the suppression of populations of wingless grasshoppers in tableland districts, they are rarely found parasitising the Australian plague locust in western districts.

After emerging from the host, worms live in the soil and their survival depends on high soil moisture levels being maintained. Infection of the host is dependent on prolonged rainy periods.

Amphimermis are widely distributed throughout the tablelands and western slopes and plains. In low rainfall areas, where conditions for survival are marginal, they are capable of asexual reproduction.

Eggs hatch in the soil during rainy periods, and the free-swimming larvae move to the surface of the soil where they locate and penetrate a host. The temperature at which larvae become active is much lower than that at which hosts are active. This enables larvae to penetrate hosts which are motionless during cool rainy periods.

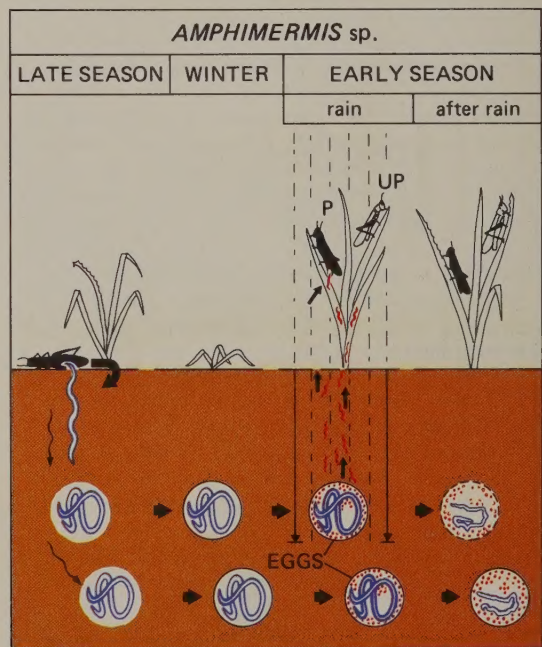
Amphimermis remain in the host for a period of 4-5 weeks during which time they grow from 2-3 mm to 150-200 mm in length.



Amphimermis eggs. Eggs massed over the walls of the earthen cell in which the female lives. The upper picture shows eggs which contain well-developed worms. These eggs will be stimulated to hatch when the cell fills with water after rain. *Amphimermis* eggs have a diameter of 180-200 micrometres, being no larger than grains of salt. (1000 micrometres equal one millimetre). (Photos: University of New England)



Nematode worm emerging from a wingless grasshopper. Feeding by nematode worms hinders sexual maturation of the host grasshopper. Parasitised nymphs are retarded in development, often failing to change to adults. The host is killed during the emergence of the nematode worm. (Photo: M. Hill)



P: parasitised

UP: unparasitised

Seasonal life cycle of *Amphimermis*. Late in the season, fully fed *Amphimermis* worms emerge from their host and enter the soil. During the winter the worms remain deep in the soil, tightly coiled in an earthen cell. In spring, females become sexually mature and commence to lay thousands of small eggs over the wall of the cell. Eggs at different stages of development are present at any one time due to protracted laying by the female. After rain, water fills the cell and those eggs which are fully developed hatch. The small infective juvenile larvae wriggle through the damp soil to the surface, where they locate and penetrate grasshopper hosts. Undeveloped eggs continue to develop and hatch in response to later rain. Eggs in cells below water penetration depth hatch in response to a later heavier fall of rain. There is no egg hatching between rainy periods.

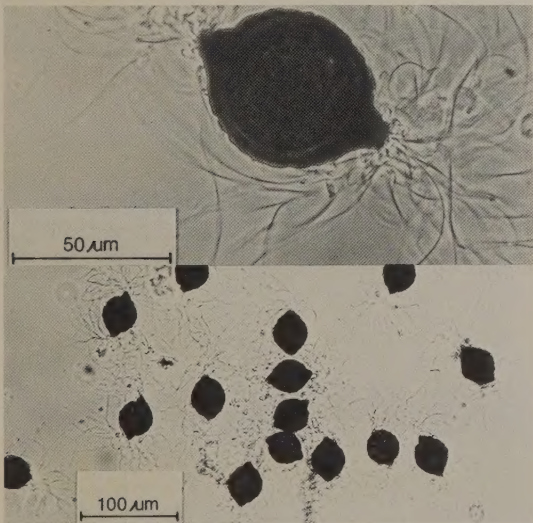
Mermis have only been recorded in tableland areas of New South Wales and in Tasmania. The species in Tasmania is *Mermis nigrescens* while the different species in New South Wales have yet to be named.

Infection of a host is by eggs laid by females on vegetation and accidentally eaten by the grasshopper.

Reproduction is sexual, females being required to mate before eggs are produced. The life-cycle is long with only a single generation being produced each season.

Rainfall is the sole factor determining when the parasites will be active, but the level of parasitism depends on several factors: the proportion of females stimulated to lay eggs during any single rainy period (dependent on the depth to which moisture penetrates); the density of eggs on the vegetation (higher on sparse pasture than on rank pasture); the period over which the eggs remain viable (dependent on temperature and intensity of sunlight); and the amount of vegetation carrying *Mermis* eggs which dries off or is eaten by stock before grasshoppers have the opportunity to feed.

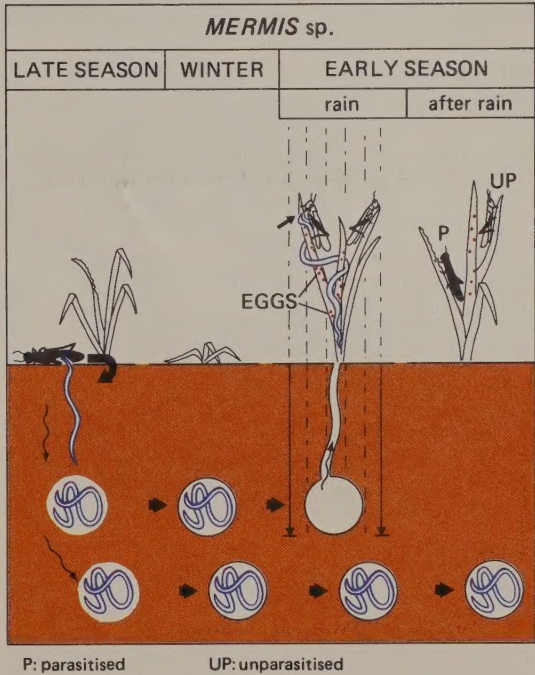
The effect of parasitism on the host population depends on when parasitism takes place: if parasitism occurs before egg laying, the next generation is greatly reduced; if parasitism occurs after egg laying, the effect on the next generation is insignificant.



Mermis eggs. Eggs laid on vegetation are transparent, colourless and extremely small, having a diameter of only 50 micrometres. They are attached to the vegetation by branched filaments extending from both ends of the egg. When eaten by the host grasshopper, the eggs hatch in the gut; the small larvae then penetrate the gut wall and enter the body cavity where they grow to 9-15 centimetres in length.



Adult female *Mermis* laying eggs over the vegetation during a rainy period. (Photo: N. Sawtel, CSIRO)



Seasonal life cycle of *Mermis*. Fully fed juvenile *Mermis* worms emerge from their host and enter the soil, penetrating to a depth of 20-40 centimetres depending on the depth at which soil moisture is adequate for survival. The juvenile moults, becoming an adult. After mating females mature and become filled with eggs. When water fills the cell during rain the female leaves the cell, emerges from the soil and moves slowly over the vegetation depositing eggs. Females below moisture penetration depth remain in their cells and later emerge after heavier rain.

HYPERPARASITES OF LOCUST PARASITES

Several of the dipterous (fly) parasites of locusts and grasshoppers are in turn parasitised themselves. Little is known, however, about the extent that these hyperparasites affect level of control by parasites on locusts and grasshoppers.

The tachinid *Ceracia fergusonii* is parasitised by the small wasp *Perilampus australis* (Hymenoptera:Pteromalidae). The young *P. australis* larva enters a grasshopper indiscriminately. If the grasshopper contains a parasite larva, the *P. australis* larva lodges under its skin and remains there until the host larva emerges from the host grasshopper. The *P. australis* larva then resumes development, consumes the parasite pupa and pupates inside it. When fully formed, the adult chews its way out of the host puparium. If young *P. australis* larvae enter a grasshopper which is not

An adult *Perilampus australis* and host puparium from which it emerged. These small metallic green and gold coloured wasps may account for the relatively minor role of the tachinid *Ceracia fergusonii* as a parasite of locusts and grasshoppers. (Photo: M. Hill)



DISEASES OF ADULTS AND NYMPHS

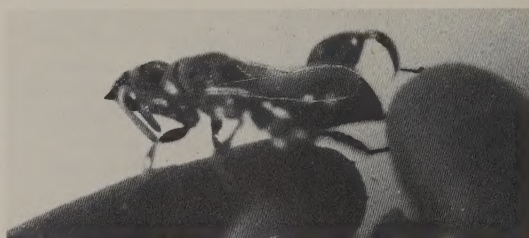
Outbreaks of disease (epizootics) in locust and grasshopper populations have been rarely recorded in Australia. This is possibly due as much to oversight as to infrequent occurrence.

No viral or bacterial diseases have been recorded and fungal diseases have only been found infrequently: the general aridity of much of Australia where locust and grasshopper outbreaks occur perhaps mitigates against fungal diseases being important. Protozoan diseases are the most frequently recorded, though there is little known about their incidence, spread or effect on grasshopper hosts.

parasitised they do no harm to the grasshopper host.

The pupal stage of both tachinid and sarcophagid parasites of locusts and grasshoppers, are parasitised by the digger wasp, *Dirhinus rufricornis* (Hymenoptera:Chalcididae). The female *D. rufricornis* locates the puparia of the grasshopper parasites in the soil and lays eggs inside. On hatching, the larva eats the host pupa, and when fully formed emerges as an adult from the host.

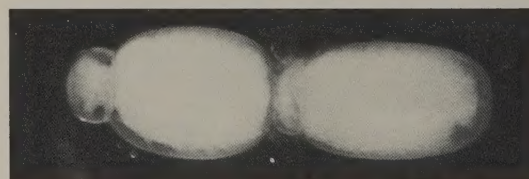
A fly, *Protomiltogramma cincta* (Diptera:Sarcophagidae:Miltogrammatinae), lays small maggots on grasshoppers captured by sphecids wasps as food for their young. The *P. cincta* maggots quickly eat the grasshopper, depriving the sphecids wasp larva of its host.



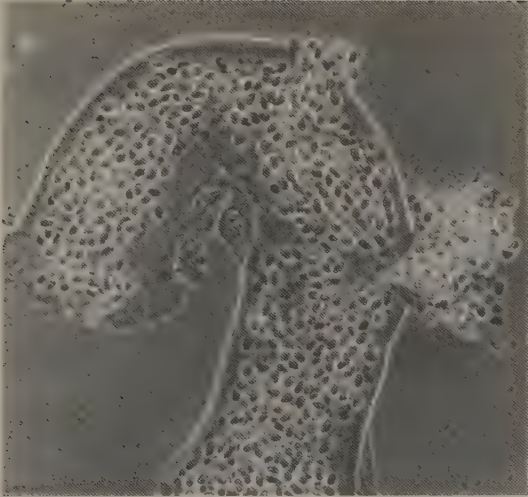
An adult female *Dirhinus rufricornis* laying an egg in a host puparium. (Photo: M. Hill)



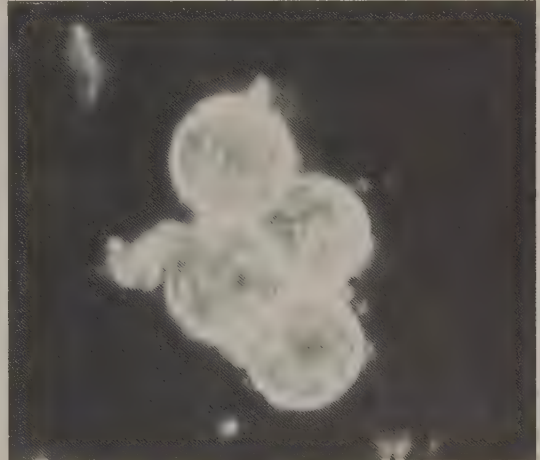
A *D. rufricornis* larva consuming a host pupa (covering of puparium removed). (Photo: M. Hill)



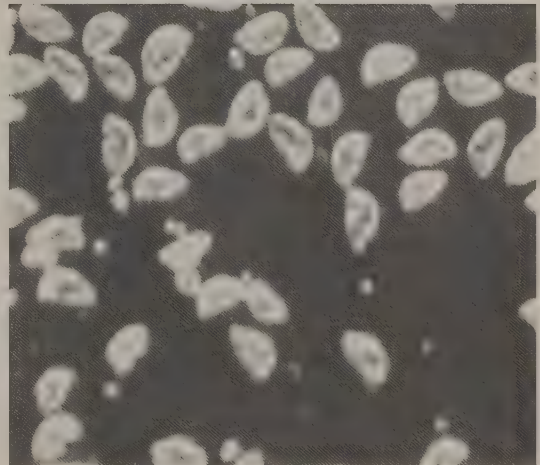
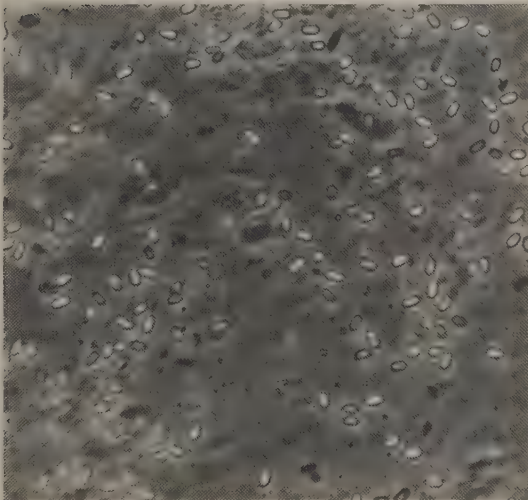
Cysts (sporonts) of *Gregarina* sp. in union in the gut of an Australian plague locust. Infection results from a grasshopper accidentally consuming spores which, when in the gut, liberate small active infective stages (sporozoites) which feed on the gut wall, dislodge when fully grown, encyst, and then pass out with the faeces, contaminating surrounding vegetation.



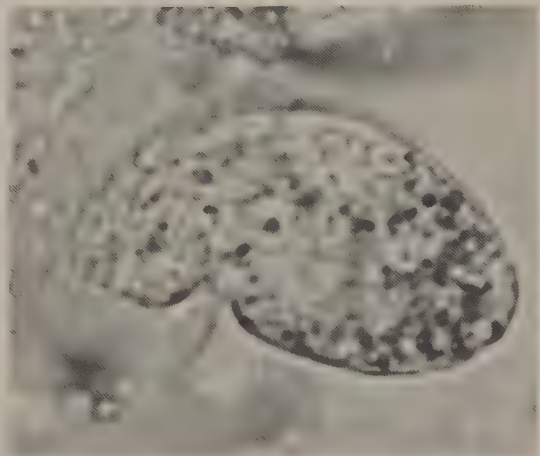
The ciliated protozoan *Colopoda* sp. (Protozoa:Trichostomatida:Colopodidae). Above, undergoing cellular division by simple transverse fission; middle, ciliates actively feeding; below, single ciliate. *Colopoda* infect the reproductive system of the female locust feeding on accessory gland secretions and oocytes in the ovaries. Infected female locusts do not lay eggs. (Photos: H.P. Ernst)



Cysts of *Malameba locustae* (Protozoa:Amoebida:Amoebidae). A heavy infestation in the malphigian tubules of a grasshopper nymph collected at Tibooburra in far western New South Wales. Hosts become infected after ingesting cysts during cannibalistic feeding on a sick or dead infected grasshopper; the cysts break down releasing small trophozoites which enter the cells lining the gut and malphigian tubules and multiply; cysts are produced in the malphigian tubules which may rupture, spreading the infection to the remainder of the grasshopper's body, killing the host. (Photos: H.P. Ernst)



Spores of *Nosema* sp. (Protozoa:Microsporidea:Nosematidae) infecting a long-horned grasshopper. *Nosema* infections have also been recorded in the wingless grasshopper, crickets and grouse-locusts (Tetrigidae). Attempts to control wingless grasshopper by spreading infected bait have so far proved unsuccessful in Australia. The *Nosema* spores are extremely small (6 micrometres in length). (Photos: H.P. Ernst)



Grasshopper killed by an infection of *Entomophthora grylli* (Phycomycetes:Entomophthorales: Entomophthoraceae). Outbreaks of fungal disease are rare requiring warm humid conditions with rainfall greater than 400 mm over the hottest months of the season. Infection occurs after spores are splashed onto the host during rain, and grow roots into the body of the host. Root fragments multiply until they fill the body cavity of the host, killing it. *E. grylli* may then produce resting spores, resistant to dry conditions, or germinate immediately, sending stalks through the dead host's skin. Each stalk produces a white spore at its end and these are discharged and scattered over surrounding vegetation. (Photo: R. Milner, CSIRO)



MITE PARASITES OF ADULTS AND NYMPHS

Body and tracheal mites (Acarina:Trombidiformes)

Mites associated with locusts and grasshoppers in Australia belong to two families, the Erythraeidae (all of which are body mites) and Podapolipodidae (both body mites and tracheal mites).

The larval stages of body mites are generally found feeding from veins on the undersurface of the wings. They are not considered harmful to the host unless a severe infestation is present. When fully engorged the larval mites drop from the host and enter the soil where, as adults, they may feed on locust and grasshopper eggs.

In the family Erythraeidae (Prostigmata) two genera of red body mites, *Leptus* and *Charletonia* (10 species), are known to be ectoparasites (parasites which occur outside the body) of locusts and

Body mites (*Podapolipus* sp.) attached to the foreleg of an Australian plague locust.



grasshoppers in Australia. The species most frequently recorded in New South Wales is *Charletonia feideria*. In the family Podapolipodidae (Tarsonemini) members of one genus, *Podapolipus*, are body mites; *Podapolipus grassi* is common in western New South Wales.

Tracheal mites enter the respiratory system and may clog major tracheae (breathing tubes) and air sacs. They are considered to be more harmful to the host than are body mites. The larvae develop into adults while in the host, reproducing several generations which may lead to severe blockage of the respiratory system.

In the family Podapolipodidae (Tarsonemini), one genus of tracheal mites, *Locustacarus*, has been recorded from Australia. Tracheal mites have been rarely recorded, but this is possibly due to the ease with which they are overlooked.

Tracheal mites (*Locustacarus* sp.). Large greenish-yellow adult female mites, small white egg clusters and larvae completely filling the air sacs of an adult grasshopper (small plague grasshopper with posterior half of abdomen removed). (Photo: B. Loudon)



PREDATORS OF ADULTS AND NYMPHS

The behaviour of predators in capturing prey is often impressive but their control of locusts and grasshoppers is generally minor. Typically their consumption capacity is limited and their appetite quickly satisfied. Predator numbers are generally low in relation to the number of prey present during outbreaks. Unlike many parasites, vertebrate predators (those with backbones) are unable to increase rapidly to take advantage of high prey numbers.

The sphecid wasp, *Prionyx saevus*; a predator of locusts and grasshoppers in the semi-arid western districts of New South Wales.



Vertebrate predators include many species of birds (the fork-tailed kite, nankeen kestrel, white and straw-necked ibis, blue martins, and ravens), small marsupials, and some other mammals (feral pigs, dogs and foxes).

Invertebrate (backboneless) predators of locusts and grasshoppers include non-specific feeders such as ants and spiders as well as more specialised feeders such as asilid flies and sphecid wasps. (See key on p. 16).

An asilid fly draws haemolymph (blood) from an immobilised wingless grasshopper.



PREDATORS OF EGG PODS

A carab larva (Coleoptera) consuming migratory locust eggs in the Moree area.



In New South Wales, egg predators are not an important cause of mortality of the egg stage of locusts and grasshoppers. Most species appear to be opportunistic feeders, only feeding on locust and grasshopper eggs under exceptional circumstances.

Egg predators are either the larval stage of some Diptera (flies), or the larval and adult stages of some Coleoptera (beetles). (See key on p. 16).

ISSN 0725-7759

Editing: John Pitt
Division of Agricultural Services

KEY TO THE PREDATORS, PARASITES AND DISEASES OF LOCUSTS AND GRASSHOPPERS

PARASITES OF EGGS

SCELIONIDAE



FLY PARASITES OF ADULTS AND NYMPHS

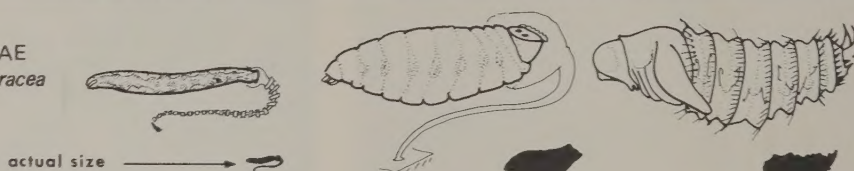
FAMILY Species

early stage LARVA

late stage LARVA

PUPA

NEMESTRINIDAE *Trichopsidea ostracea*



TACHINIDAE *Ceracia fergusonii*

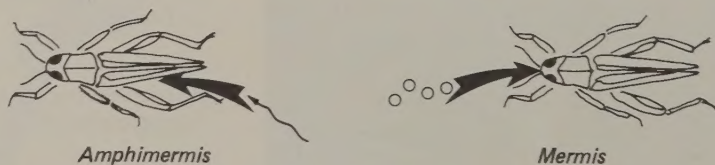


SARCOPHAGIDAE *Blaesoxipha pachytyli*



NEMATODE PARASITES OF ADULTS AND NYMPHS

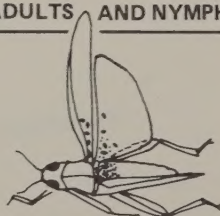
ERMITHIDAE (NEMATODA)



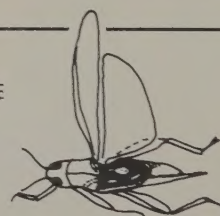
MITE PARASITES OF ADULTS AND NYMPHS

Body mites ERYTHRAEIDAE *Leptus charletonia*

PODAPOLIPODIDAE *Podapolipus*



Tracheal mites PODAPOLIPODIDAE *Locustacarus*

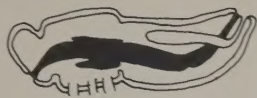


KEY TO THE PREDATORS, PARASITES AND DISEASES OF LOCUSTS AND GRASSHOPPERS

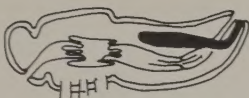
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DISEASES OF ADULTS AND NYMPHS

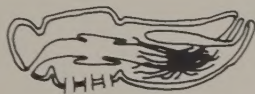
PROTOZOAN



Gregarina



Colopoda



Malameba



Nosema

FUNGAL



Entomophthora

PREDATORS OF EGG PODS

ORDER

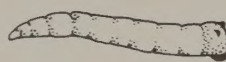
FAMILY
Species

DIPTERA

(FLIES)



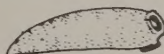
CALLIPHORIDAE
Stomorphina discolor



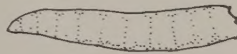
PLATYSTOMATIDAE
Elassogaster sepsoides



BOMBYLIIDAE
Crytomorpha flaviscutellaris



SARCOPHAGIDAE
Heteronchyia australis



ANTHOMYIIDAE
Delia platura



COLEOPTERA

(BEETLES)



MELYRIDAE
Laius villosus



TENEBRIONIDAE
several species



CARABIDAE
several species

INVERTEBRATE PREDATORS OF ADULTS AND NYMPHS



SPHECIDAE (HYMENOPTERA)
Prionyx saevus



Isodontia



ASILIDAE (DIPTERA)

PREDATORS

FLY LARVAE (DIPTERA)	
Bombyliidae	
<i>Cyrtomophya flavicollis</i> Roberts	Small plague grasshopper
	Australian plague locust
Calliphoridae	
<i>Stomoxys calcitrans</i> (L.)	Yellow-winged locust
Sarcophagidae	
<i>Heimerichia australis</i> (L. & T.)	Migratory locust
Phlebotomidae	
<i>Elaeophaga sp.</i> (Walker)	Wingless grasshopper
Anthomyiidae	
<i>Delia platura</i> Meigen	Australian plague locust

BEETLE LARVAE (COLEOPTERA)	
Anthicidae	
<i>Anthicus</i> sp.	Australian plague locust
Meloidae	
<i>Lasius villosus</i> Lea	Australian plague locust
Carabidae	
Several species	Wingless grasshopper
Tenebrionidae	
Several species	Australian plague locust

INVERTEBRATE PREDATORS	
Hymenoptera : Sphecidae	Australian plague locust (adult females)
<i>Proctos</i> sp. (Smith) *	Australian plague locust (nymphs)
<i>Isodonta</i> sp.	
Diptera : Asilidae	
Several spp.	Many species of locusts and grasshoppers
Hemiptera : Reduviidae	
<i>Coreus trabeatus</i> Horv.	Yellow-winged locust (nymphs)
SECONDARY PARASITE	
Diptera : Sarcophagidae	
<i>Protonilogramma cincta</i> Townsend *	(above)

INSECTIVOROUS BIRDS	
<i>Milvus migrans</i> Boddart	(fork-tailed kite)
<i>Falco cinereus</i> Vigors and Horsfield	(nankeen kestrel)
<i>Threskiornis melu</i> Cuvier	(white ibis)
<i>Threskiornis aeneus</i> Jameson	(straw-necked ibis)
<i>Ardea herodias</i> Gould	(blue heron)
<i>Corvus coronoides</i> Vigors and Horsfield	(raven)

HOST STAGE

EGG PODS

SCLEONID EGG PARASITES (HYMENOPTERA)	
Scelionidae	
<i>Scelio fulgidus</i> Crawford	Australian plague locust
<i>Scelio parvicornis</i> Dodd	Australian plague locust
<i>Scelio bipartitus</i> Krieger	Yellow-winged locust
<i>Scelio improbus</i> Dodd	Wingless grasshopper
<i>Scelio chortolices</i> Froggat	Small plague grasshopper

FLY PARASITES (DIPTERA)	
Nemestrinidae	
<i>Trichopoda oestracae</i> Westwood	Many species of locusts and grasshoppers
Tachinidae	
<i>Cercia fergusoni</i> Malloch *	Many species of locusts and grasshoppers
Sarcophagidae	
<i>Blaesoxipha pachyrrhynchos</i> (Skuse) †	Many species of locusts and grasshoppers
<i>Blaesoxipha gracilis</i> (Skuse) †	Many species of locusts and grasshoppers
<i>Blaesoxipha similis</i> Central	Spur-throated locust

HYPERPARASITES	
Hymenoptera : Peromalidae	
<i>Perilampus australis</i> Graust *	(above)
Hymenoptera : Chalcididae	
<i>Dinichus ruficornis</i> (Graust) †	(above)

NEMATODE WORMS (NEMATODA)	
Mermithidae	
<i>Mermis</i> sp.	Many species of locusts and grasshoppers
<i>Amphimermis</i> sp.	Many species of locusts and grasshoppers

BODY MITES (ACARINA)	
Erythraeidae	
<i>Charitonia feideri</i> Southcott	Many species of grasshoppers and locusts
<i>Charitonia</i> spp.	
<i>Leptus</i> spp.	
Podapolipodidae	
<i>Podapolipus grasi</i> Berlese	Many species of grasshoppers and locusts

TRACHEAL MITES (ACARINA)	
Podapolipodidae	
<i>Locustacarus</i> spp.	Small plague grasshopper

ADULTS AND NYMPHS

DISEASES	
Phycomycetes : Entomophthoraceae	
<i>Entomophthora grylli</i> Fries	Many species of locusts and grasshoppers but not all are equally susceptible
Sporozoa : Gregarinidae	
<i>Gregarina</i> spp.	Many species of locusts and grasshoppers
Amoebidae : Amoebidae	
<i>Melambol locustae</i> (King & Taylor)	Many species of locusts and grasshoppers
Microsporidia : Nosematidae	
<i>Nosema</i> sp.	Several species of grasshoppers and crickets
Trichostomatida : Colopodidae	
<i>Colopoda</i> sp.	Wingless grasshopper